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1.	Your reference	AMBA198
2.	Patent application number *(The Patent Office will fill in this part)*	0220159.8 — 30 AUG 2002
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	Ashe Morris Limited 6 Christchurch Crescent 8135311001 Radlett Hertfordshire, WD7 8AH
	Patents ADP number *(if you know it)*	
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	IMPROVED HEAT EXCHANGER
5.	Name of your agent *(if you have one)*	BAWDEN, Peter Charles
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Bawden & Associates 4 The Gatehouse 2 High Street Harpenden Herts AL5 2SP
	Patents ADP number *(if you know it)*	07703572002

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number or earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* — YES

a) any applicant named in part 3 is not an inventor, or
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See note (d))

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Continuation sheets of this form	
Description	6
Claim*(s)*	3
Abstract	1
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11. I / We request the grant of a patent on the basis of this application.

Signature P. Bawden Date 30 Aug 02

12. Name and daytime telephone number of person to contact in the United Kingdom: Peter Charles BAWDEN 01582 466700

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IMPROVED HEAT EXCHANGER

Summary

The present invention relates to an improved method for designing and fabricating heat exchangers of the type that currently use external heating or cooling jackets, external coils or external half coils. We have found that better heat exchanger performance (in terms of temperature control and heat transfer capacity) can be achieved by using multiple small heat transfer elements rather than a single large jacket or a few large half coil elements.

Whilst some heat exchangers (such as multiple half coils and split jackets) use more than one element, the number of these elements is restricted by the cost and complexity of fabrication. Conventional wisdom dictates that heat transfer fluid turbulence should be maximised and the thickness of material between the heat transfer fluid and the process fluid should be minimised for good heat transmission. The underlying basis of this invention is that these design criteria can be relaxed by using a greater number of much smaller pipes (carrying the heat transfer fluid) and using the full wetted perimeter of the pipes for heat transmission. To achieve this, complete pipes rather than half coils or jackets are used. By using complete pipes there is much less restriction on choice of material (since they only need be bolted, glued, bonded or soldered rather than welded to the body of the vessel, although welding can also be used). Thus for example the heat transfer pipe can be fabricated in a material with high thermal conductivity such as copper and fixed to a glass or Hastelloy vessel. Not only does a small diameter copper pipe have a better wetted surface to volume ratio but it can transmit heat to and from the heat transfer fluid around the full wetted perimeter. Because the pipe is small, the maximum distance between any part of the copper and the vessel surface is always relatively small. A further development of this concept is the use of pipes with a flat side to give a larger area of contact between the pipe carrying the heat transfer fluid and the wall of the process equipment. The result is a jacketed heat exchanger with multiple independent heat transfer elements. This design not only gives better performance but it is cheaper and simpler to fabricate.

Description

The present invention relates to heat exchangers. Heat exchangers are essential for many industrial, commercial and domestic purposes. They are used to add or remove heat during processes such as exothermic or endothermic reactions, evaporation, distillation

and crystallisation etc. They are also used to modify the temperature of the materials in a wide range of industrial, commercial and domestic operations.

The present invention reflects the fact that better heat exchanger performance (in terms of improved temperature control and higher heat transfer capacity) can be achieved if the heat transfer surface is broken up into a large number of small elements each with an independent supply of heat transfer fluid. We have found that the use of multiple heat transfer elements permits shorter residence time of the heat transfer fluid, better distribution of the heat transfer fluid and a lower pressure drop (for a given cross sectional area of the heat transfer fluid conduit) due to the shorter path length.

Building heat exchangers with multiple flow elements can be costly if conventional fabrication techniques are used. Some alternative methods can be used but incur a penalty in terms greater heat transfer resistance at the heat transfer boundary. The present invention provides a low cost method of building multi element (with cross flow of the heat transfer fluid) heat exchangers that give better performance.

Many types of heat exchanger exist such as plate type, shell and tube, batch reactors etc. The types relevant to this description are heat exchangers where the following conditions apply:

(a) Heating and cooling is by an indirect method across some form of containment wall (referred to as the heat transfer wall).
(b) The heat transfer surface is at the external boundary of the process fluid.
(c) The flow of heat transfer fluid is broken up into two or more separate elements.

Examples of heat transfer equipment that comply with (a), (b) and (c) above are shown in Figures 1 and 2.

A jacketed vessel will be used for this description. Two common fabrication methods for batch vessels are shown in Figures 3 and 4.

Figure 3 shows a conventional jacketed vessel. Whilst the performance of the jacket can be improved by injection nozzles or baffles, a more effective design is the half coil configuration shown in Figure 4. The half coil offers better fluid distribution and better heat transfer performance. It is formed by cutting a pipe in half longitudinally and wrapping it around the body of the vessel. In this case, the half coil is shown as two separate pipes.

By using several pipes according to the present invention rather than one, the need for excessively large pipes and very high flow rates (of heat transfer fluid) can be avoided. Half coil reactors in current service usually have two or three separate elements.

The present invention therefore provides a heat exchanger in which heat transfer fluid is delivered to the heat transfer surface via multiple fully contained conduits which are separate but in intimate contact with the heat transfer surface wherein good contact between the conduit and the heat transfer surface is only required for good heat transmission and not for fluid containment.

The half coil jacket represents an improvement over the single jacket design. A further improvement can be made by breaking the half coil into a much larger number of small coils according to the present invention as shown in Figure 5.

In this case the coil has been reduced to a series of single hoops resulting in much shorter flow paths. This design offers faster replacement of heat transfer fluid which is desirable for good temperature control. The average temperature difference (between the heat transfer fluid and the process fluid) can also be higher than that of the half coil design since the fluid is only making a single turn rather than many turns. The individual coils preferably have cross sectional flow areas of $500mm^2$ or less, preferably $200mm^2$ or less, more preferably $100mm^2$ of less, more preferably $20mm^2$ or less and sometimes $1mm^2$ or less.

Whilst the multiple hoop solution has advantages, the half coil design is relatively costly to fabricate. An illustration of the conventional half coil fabrication method is shown in Figure 6.

A conventional half coil jacket is made from a pipe cut in half longitudinally and wrapped around the heat transfer surface. The half coil is then welded to the heat transfer surface along its full length to form a continuous contained flow channel for the heat transfer fluid. At the start and end of the half coil, a transition from half coil to full pipe has to be made to connect it to the supply and return pipes. This is a relatively complex and time-consuming method of fabrication. A further implication of using multiple feed and take off points (of heat transfer fluid) has to be considered. As the number of feed and take off points increases, the pipe diameter gets smaller (unless very high flow rates of heat transfer fluid are to be used) and a much large number of smaller pipes are needed to cover the surface area. This increases the fabrication cost substantially.

An alternative design method is to use a complete pipe as shown in Figure 7.

In Figure 7, fabrication of the inlet and take off points are simplified since these are a continuation of the pipe. The need to cut the pipe longitudinally is also eliminated. An additional and major advantage is that a substantially different material can be used for the heat transfer pipe. This arises because no welding is required to maintain containment integrity of the heat transfer fluid. Thus the heat transfer pipe (or conduit) can be joined to the heat transfer surface by bolting, screwing, soldering, braising or gluing to the heat transfer surface (it should be noted that bolting and screwing are less desirable since they do not necessarily eliminate the air gap between the pipe and the heat transfer surface). This permits the use of materials with better thermal conductivity (such as copper or aluminium). A disadvantage with this method is that the geometric profile of a round pipe section increases the distance between the heat transfer fluid and the process fluid. This increases the thermal resistance. This is compensated for to some extent by the fact that smaller heat transfer pipes are used. In this case the bonding material for the pipe to the body of the vessel should have good thermal conductivity properties.

A further improvement to the full pipe solution is to use a pipe (or conduit) that has a flat side in contact with the heat transfer surface as shown in Figure 8.

As Figure 8 shows, the pipe cross section can be square, rectangular, D shape, triangular or any other shape providing a flat face is in contact with the heat transfer surface. Today there are methods of fabricating copper pipes (and other materials) with unusual profiles. It is also possible to fabricate pipes of this shape and retain the round ends. By retaining the round ends, joining of the end connections to the manifold is simplified.

Because the pipe is complete (and not cut through longitudinally), no welding is required. It is important however to eliminate air gaps between the pipe (carrying the heat transfer fluid) and the heat transfer surface. For this reason, the pipe is preferably fixed to the heat transfer wall by a continuous layer of material with good thermal conductivity. Suitable materials include: solder, silver solder, braising, thermally conductive cements or any other bonding material with good thermally conductive properties.

Although soft materials such as copper have less strength, this is compensated for by the fact that smaller diameter pipes have inherently higher design pressures. The pipes have smaller diameters by virtue of the fact that a much greater number of them are used.

The heat transfer characteristics of the flat-sided full coil of the invention are different to the conventional half coil as illustrated in Figure 9 which shows the heat transfer mechanism of a half coil compared to a modified full coil design.

In the case of the half coil, the cross sectional area of flow is relatively large (typically >500 mm^2) and the flow conditions are generally turbulent. Turbulent flow is desirable for good heat transmission between the heat transfer fluid and the heat transfer surface. The absence of a pipe wall on the process side of the half coil is also desirable since this reduces the distance that heat has to flow between the heat transfer fluid and the process fluid. The half pipe wall is fabricated in a material which can be welded to the heat transfer wall. This is usually steel or stainless steel. Whilst some heat will be transmitted via the walls of the pipe, this is a relatively small proportion of overall heat transferred.

In the case of the modified full coil shown in Figure 9, the cross sectional area is small (usually <500 mm2 and more generally <100 mm^2) and the flow conditions will often be laminar. The full coil method also has an additional layer of material between the process fluid and the heat transfer wall. On the face of it, the laminar flow conditions and additional wall thickness might suggest inferior heat transfer properties. In practice the opposite is true. Although laminar flow is not ideal for good heat transfer, pipes used in the multi pipe solution have much smaller diameters. The small diameter offers a larger wall surface area per unit volume of heat transfer fluid. Given that very thermally conductive pipes can be used (the thermal conductivity of copper for example is more than 20 times higher than that of stainless steel), the full wetted circumference of the heat transfer pipe can be exploited for heat transmission as shown by the arrows in the diagram above. A variety of internal shapes can also be used to increase the surface to volume relationship. If necessary more elaborate shapes can be used to exploit the high thermal conductivity of materials like copper. Some examples are shown in Figure 10.

A further improvement in performance can be achieved by inserting baffles and flow disrupters within the pipes.

A jacketed vessel or jacketed pipe fabricated with numerous small conductor pipes has different appearance to conventional jacketed heat exchangers as shown in Figure 11.

The design as shown in Figure 11 has many advantages:

- The conductor pipes are simple to fix to the vessel by bolting, screwing, soldering, braising or gluing. (Note that bolting and screwing are not ideal in some cases as these methods may leave an air gap)
- The conductor pipes are also simple to connect to the manifold since they can be fabricated with circular end profiles thus they can be connected with soldering, braising or compression fittings.
- The conductor pipes give improved heat transfer capacity and faster fluid replacement speeds.
- The small diameters of the conductor pipes make them comparatively strong.
- The conductor pipes can be repaired and replaced in situ.
- The design can be used with any vessel material such as glass, glass lined steel, stainless steel, carbon steel, Hastelloy etc.

This design not only delivers better performance for jacketed vessels and pipes, but will be simpler and cheaper to build. The number and size of the conductor pipes will depend upon the size of the vessel whose temperature is to be controlled and the nature of the medium who temperature is to be controlled. However as many as several hundred pipes could be employed on a large vessel.

Typically the invention employs from 5 to 100 conduits. Preferably 5 or more, more preferably 10 or more, most preferably 50 or more. In the case of large vessels 100 or more conduits for example up to 250 conduits may be used.

CLAIMS

1. A heat exchanger in which heat transfer fluid is delivered to the heat transfer surface via multiple fully contained conduits which are separate but in intimate contact with the heat transfer surface wherein good contact between the conduit and the heat transfer surface is only required for good heat transmission and not for fluid containment.

2. A heat exchanger according to Claim 1 where the heat transfer fluid conduit has at least one side flattened in cross sectional view and this side is held in intimate contact with or joined to the heat transfer surface.

3. A heat exchanger according to either of Claims 1 or 2 where the heat transfer conduit is made from a single piece of material or two pieces of material joined in the longitudinal axis and the cross sectional profile of the flow path of the conduit is modified to different shapes so as to improve the ratio of wetted area of the conduit to conduit volume.

4. A heat exchanger according to any of the Claims 1 to 3 where 5 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

5. A heat exchanger according to any of the Claims 1 to 3 where 10 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

6. A heat exchanger according to any of the Claims 1 to 3 where 50 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

7. A heat exchanger according to any of the Claims 1-to 3 where 100 or more conduits are used to deliver heat transfer fluid to the heat transfer surface.

8. A heat exchanger according to any of the preceding Claims where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 500 mm^2 or less.

9. A heat exchanger according to any of the Claims 1 to 7 where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 100 mm^2 or less.

10. A heat exchanger according to any of the Claims 1 to 7 where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 20 mm^2 or less.

11. A heat exchanger according to any of the Claims 1 to 7 where two or more of the conduits delivering heat transfer fluid have cross sectional flow areas of 1 mm^2 or less.

12. A heat exchanger according to any of the preceding Claims where the conduits used to deliver the heat transfer fluid to the heat transfer surface are made of material having a thermal conductivity of greater than 100 W/m.k.

13. A heat exchanger according to any of the Claims 1 to 12 where the conduits used to deliver the heat transfer fluid to the heat transfer surface are made of material having a thermal conductivity of greater than 10 W/m.k.

14. A heat exchanger according to any of the Claims 1 to 13 where the conduits used to deliver the heat transfer fluid are made of copper or copper alloy.

15. A heat exchanger according to any of the preceding Claims which controls the process temperature by varying the heat transfer area.

16. A heat exchanger according to any of the preceding Claims which delivers heat transfer fluid by cross flow.

17. A heat exchanger according to any of Claims 1 to 16 that is a batch reactor.

18. A heat exchanger according to any of Claims 1 to 16 that is a continuous reactor.

19. A heat exchanger according to any of Claims 1 to 16 that is used for heat transfer in nuclear reactions.

20. A heat exchanger according to any of Claims 1 to 18 that is a crystalliser.

21. A heat exchanger according to any of Claims 1 to 18 that is used for fermentation or growth of plant or animal cells.

22. A heat exchanger according to any of Claims 1 to 18 that is used for evaporation or drying

23. A heat exchanger according to any of Claims 1 to 18 that is used for distillation.

24. A heat exchanger according to Claims 1 to 18 that is used to heat or cool supercritical fluids.

25. A heat exchanger according to Claim 24 that is used to heat or cool supercritical fluids during expansion.

26. A heat exchanger according to any of Claims 1 to 25 that is used in food manufacturing processes.

27. A heat exchanger according to any of Claims 1 to 25 that is used for manufacturing pharmaceutical compounds.

28. A heat exchanger according to any of Claims 1 to 25 that is used for chemical manufacturing processes.

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ABSTRACT

A heat exchanger in which heat transfer fluid is delivered to a heat transfer surface via multiple fully contained conduits which are separate but in intimate contact with the heat transfer surface. Good contact between the conduit and the heat transfer surface is only required for good heat transmission and not for fluid containment. Typically 5 or more conduits are used to deliver heat transfer fluid to the heat transfer surface and the conduits have cross sectional flow areas of 500 mm^2 or less.

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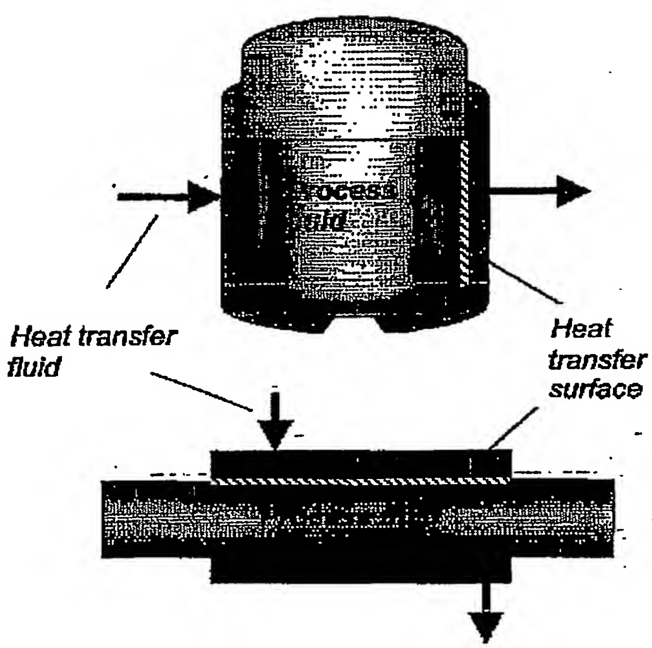
Figure 1.
Batch vessel

Figure 2.
Jacketed pipe



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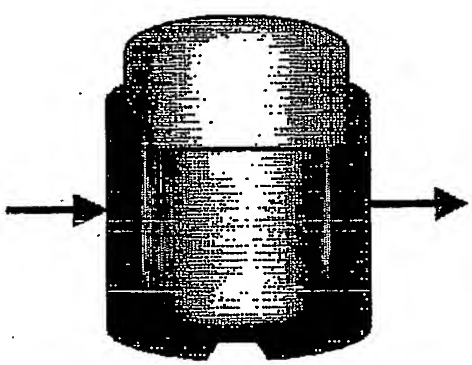

Figure 3.
Conventional jacket

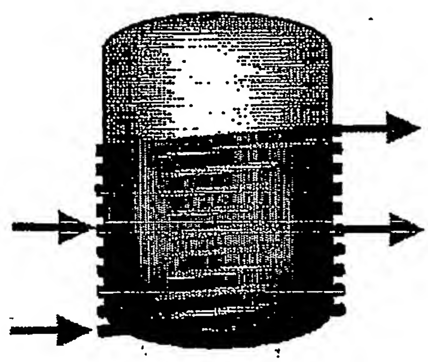

Figure 4.
Half coil jacket
(with two feed and two discharge points for the heat transfer fluid).

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Figure 5.
Half coil jacket with multiple take offs.
(This could also be described as a type of cross flow (of the heat transfer fluid) heat exchanger.

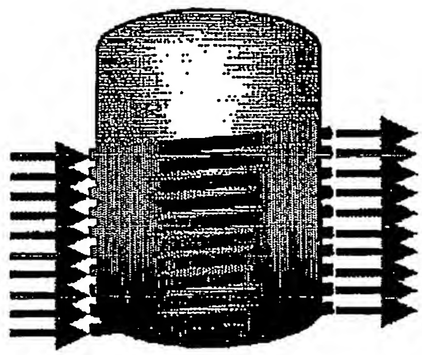

Figure 6.
Section through a half coil heat exchanger

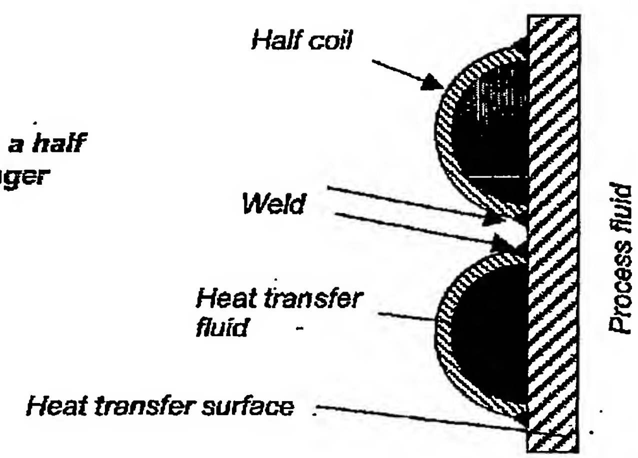

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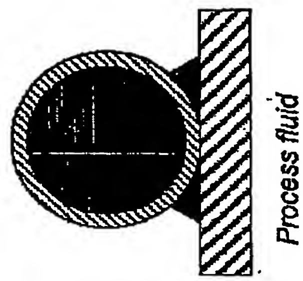
Figure 7.
Heat transfer fluid pipe welded to heat transfer surface.



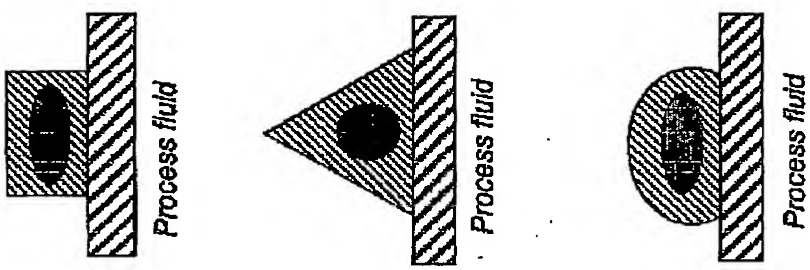
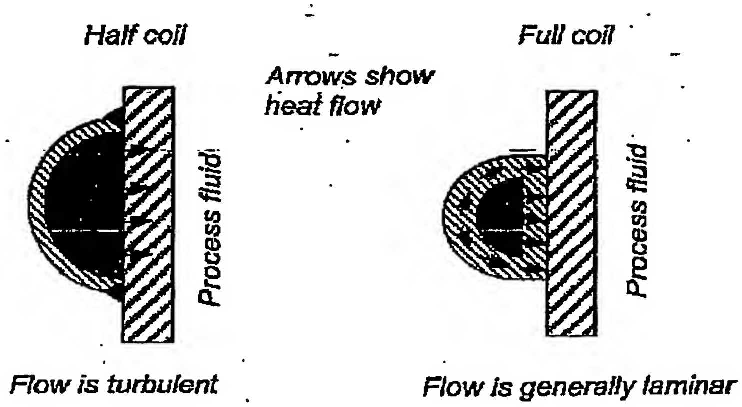


Figure 8 Some Alternative shapes for flat-sided heat transfer fluid pipe

Figure 9.
Heat flow in half coil and flattened full coil.



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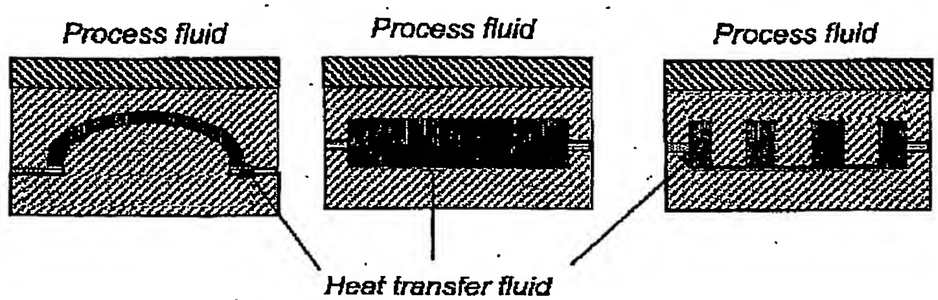
Two piece heat transfer fluid pipes (two halves are soldered, braised or glued together)



Solid heat transfer fluid pipes

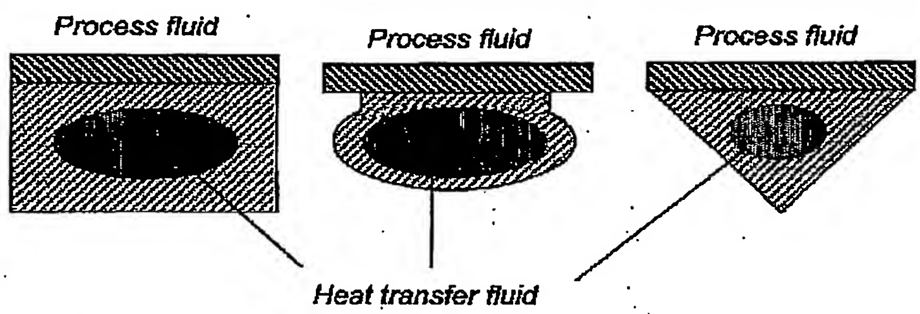


Figure 10.
Examples of heat transfer conduits with different internal and external profiles as shown in cross section.

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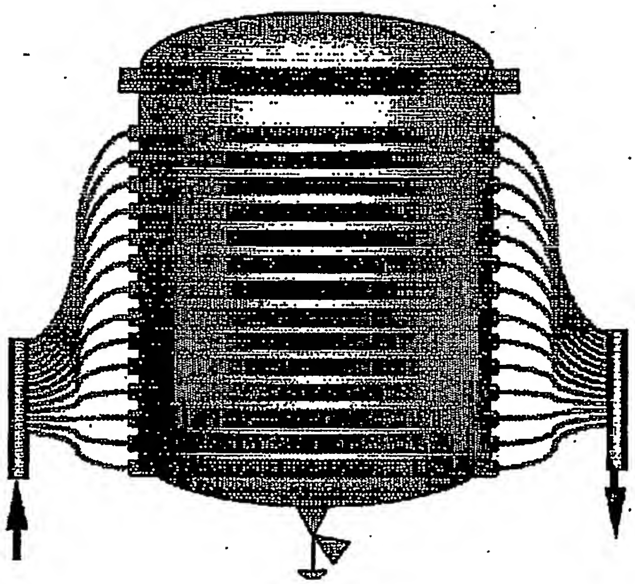

Figure 11.
Multi tube jacketed vessel using copper conductor pipes (the conductor pipes may number several hundred on a large vessel).